

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In the Patent Application of:

Alexander Lidow et al

Date: February 8, 1991

Serial No.:

Group Art Unit:

Filed:

Examiner:

For: PLURAL POLYGON SOURCE PATTERN FOR MOSFET

AMENDMENT TRANSMITTAL LETTER - FEE COMPUTATION

Commissioner of Patents and Trademarks
Washington, DC 20231

Transmitted herewith is an amendment in the above-identified application.

 "Small Entity" Status under 37 C.F.R. §1.9 and §1.27 established
 previously by enclosed verified statement.

Fees have been calculated as shown below:

			SMALL ENTITY				NON-SMALL ENTITY			
CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NO. PREVIOUSLY PAID FOR		PRESENT EXTRA		RATE	ADDIT. FEE	OR	RATE	ADDIT. FEE
TOTAL 8	MINUS	20	* =	0	x	\$10	\$		\$20	\$ 0
INDEP. 4	MINUS	3	** =	1	x	\$30	\$		\$60	\$60.00
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM						\$100	\$		\$200	\$ 0
* not less than 20 ** not less than 3						TOTAL	\$		TOTAL	\$60.00

OFGS Check No. 019664 which includes the fee of \$60.00 is attached.

In the event the actual fee is greater than the payment submitted or is inadvertently not enclosed or if any additional fee during the prosecution of this application is not paid, the Patent Office is authorized to charge the underpayment to Deposit Account No. 15-0700. A duplicate copy of this sheet is enclosed.

If this communication is filed after the shortened statutory time period had elapsed and no separate Petition is enclosed, the Commissioner of Patents and Trademarks is petitioned, under 37 C.F.R. §1.136(a), to extend the time for filing a response to the outstanding Office Action by the number of months which will avoid abandonment under 37 C.F.R. §1.135. The fee under 37 C.F.R. §1.17 should be charged to our Deposit Account No. 15-0700. A duplicate copy of this sheet is enclosed.

EXPRESS MAIL CERTIFICATE

I hereby certify that this correspondence is being deposited with the United States Postal Service as Express Mail Post Office to Addressee (mail label #B68500860 in an envelope addressed to: Commissioner of Patents and Trademarks, Washington, DC, 20231, on February 8, 1991

Name of Person mailing Correspondence

Signature

February 8, 1991

Date of Signature

Respectfully submitted,

Samuel H. Weiner

Registration No.: 18,510
OSTROLENK, FABER, GERB & SOFFEN
1180 Avenue of the Americas
New York, New York 10036-8403
Telephone: (212) 382-0700

PATENT APPLICATION SERIAL NO. 07/653017

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE
FEE RECORD SHEET

07/653017

GPO L.H. 02/14/91 07653017

1 101 690.00 CK IR-1013-CONT

[54] PLURAL POLYGON SOURCE PATTERN FOR MOSFET

[75] Inventors: Alexander Lidow, Manhattan Beach; Thomas Herman, Redondo Beach; Vladimir Rumennik, El Segundo, all of Calif.

[73] Assignee: International Rectifier Corporation, El Segundo, Calif.

[*] Notice: The portion of the term of this patent subsequent to Apr. 16, 2008 has been disclaimed.

[21] Appl. No.: 653,017

[22] Filed: Feb. 8, 1991

Related U.S. Application Data

[63] Continuation of Ser. No. 291,423, Dec. 23, 1988, Pat. No. 5,008,725, which is a continuation of Ser. No. 243,544, Mar. 13, 1981, abandoned, which is a continuation of Ser. No. 38,662, May 14, 1979, abandoned.

[51] Int. Cl.⁵ H01L 29/78
[52] U.S. Cl. 357/23.4; 357/23.1; 357/23.14; 357/45
[58] Field of Search 357/23.1, 23.4, 23.14, 357/45

[56] References Cited

U.S. PATENT DOCUMENTS

3,484,865 12/1969 Nienhuis 357/23.4
3,786,319 1/1974 Tomisaburo 357/23.4
4,015,278 3/1977 Fukuta 357/23.4
4,072,975 2/1978 Ishitani 357/23.4
4,145,700 3/1979 Jambotkar 357/23.4
4,145,703 3/1979 Blanchard et al. 357/23.4
4,148,047 4/1979 Hendrickson 357/23.4
4,173,022 10/1979 Dingwall 357/23.4
4,206,469 6/1980 Hanes et al. 357/23.4
4,376,286 3/1983 Lidow et al. 357/23.4
4,399,449 8/1983 Herman et al. 357/23.4
4,593,302 6/1986 Lidow et al. 357/23.4
4,680,853 7/1987 Lidow et al. 357/23.4
5,008,725 4/1991 Lidow et al. 357/45

FOREIGN PATENT DOCUMENTS

51-85381 7/1976 Japan 357/23.4
54-885 1/1979 Japan 357/23.4
1153428 5/1969 United Kingdom 357/23.4
1224335 3/1971 United Kingdom 357/23.4
1372086 10/1974 United Kingdom 357/23.4
1390135 4/1975 United Kingdom 357/23.4
1400574 7/1975 United Kingdom 357/23.4
145580 11/1976 United Kingdom 357/23.4
1465244 2/1977 United Kingdom 357/23.4

OTHER PUBLICATIONS

R. C. Cady, Jr. and R. R. Silverman, Integration Technique for Closed Field-Effect Transistors, Apr. 1974, IBM Technical Disclosure Bulletin, vol. 16, Nov. 11, pp. 3519-3520.
H. William Collins, The Hexfet: A new high in power MOS, Jun. 7, 1979, Electronic Design.

Primary Examiner—Rolf Hille

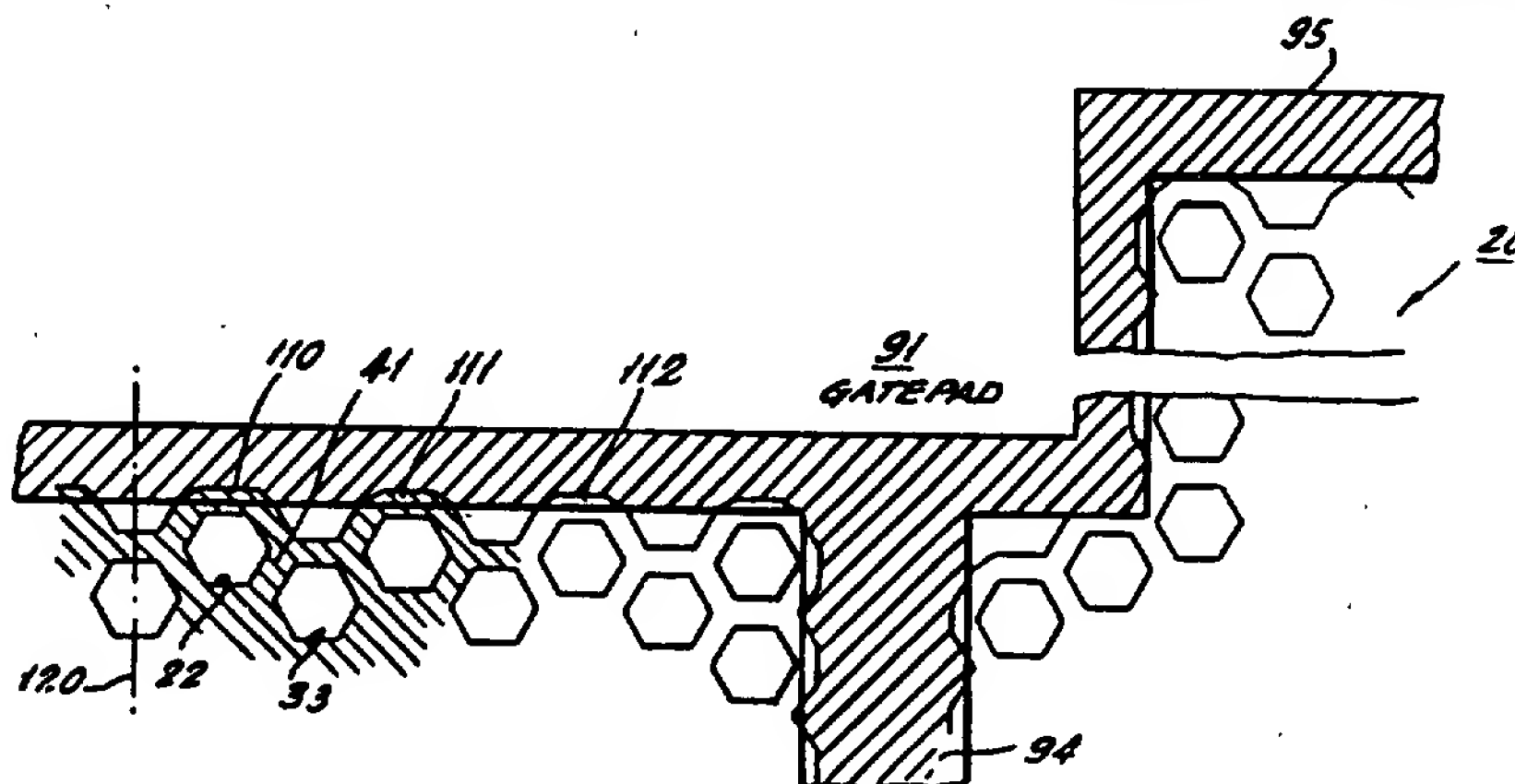
Assistant Examiner—Steven Loke

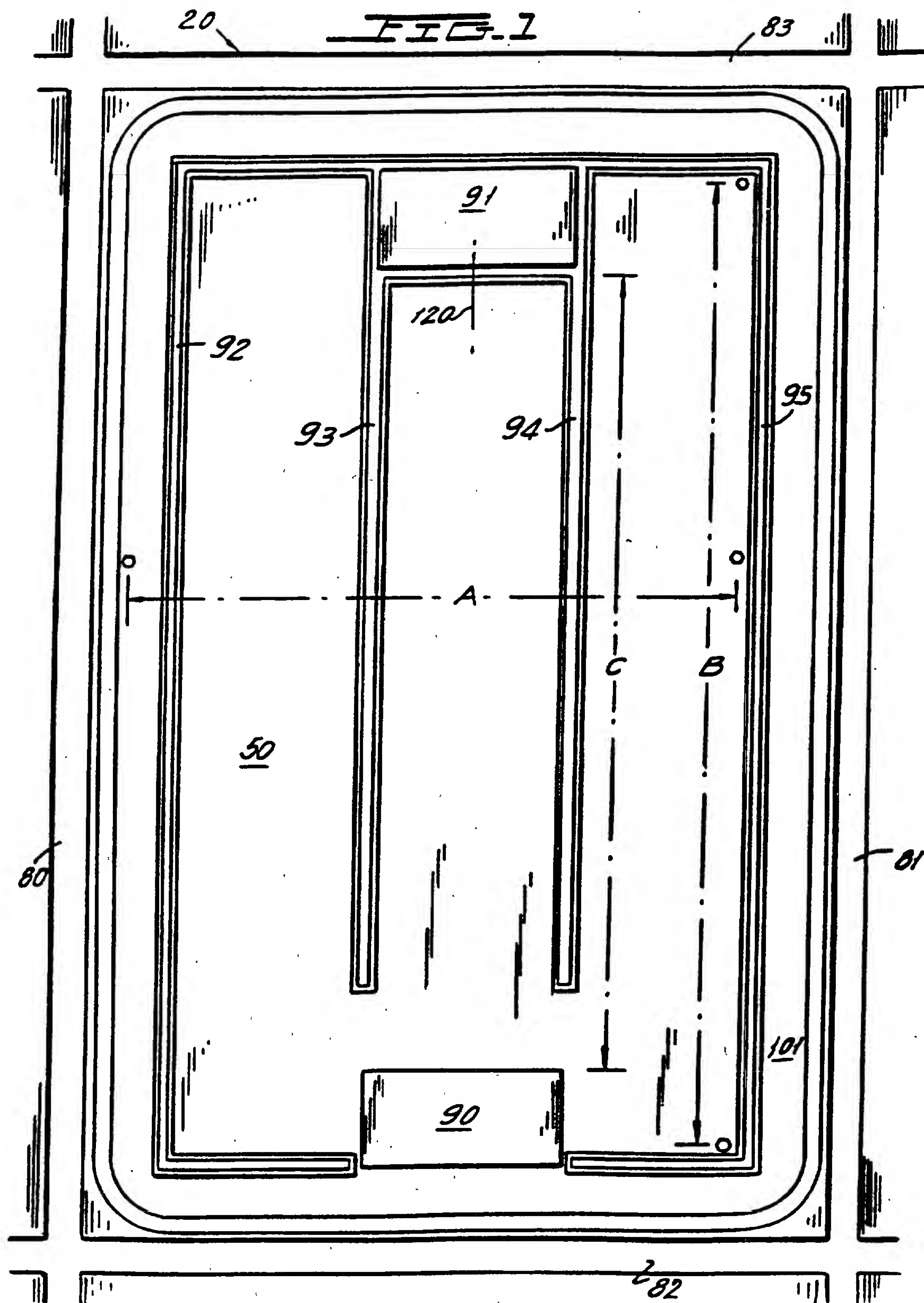
Attorney, Agent, or Firm—Ostrolenk, Faber, Gerb & Soffen

[57] ABSTRACT

A high power MOSFET has a plurality of closely packed polygonal sources spaced from one another on one surface of a semiconductor body. An elongated gate electrode is exposed in the spacing between the polygonal sources and cooperates with two channels, one for each adjacent source electrode, to control conduction from the source electrode through the channel and then to a drain electrode on the opposite surface of the semiconductor body. The conductive region adjacent the channel and between adjacent sources is relatively highly conductive in the section of the channel adjacent to the surface containing the sources. The polygonal shaped source members are preferably hexagonal so that the distance between adjacent sources is relatively constant throughout the device. Each polygonal region has a relatively deep central portion and a shallow outer shelf portion. The shelf generally underlies an annular source region. The deep central portion underlies an aluminum conductive electrode and is sufficiently deep that it will not be fully penetrated by aluminum spiking.

8 Claims, 3 Drawing Sheets





07-69017-0

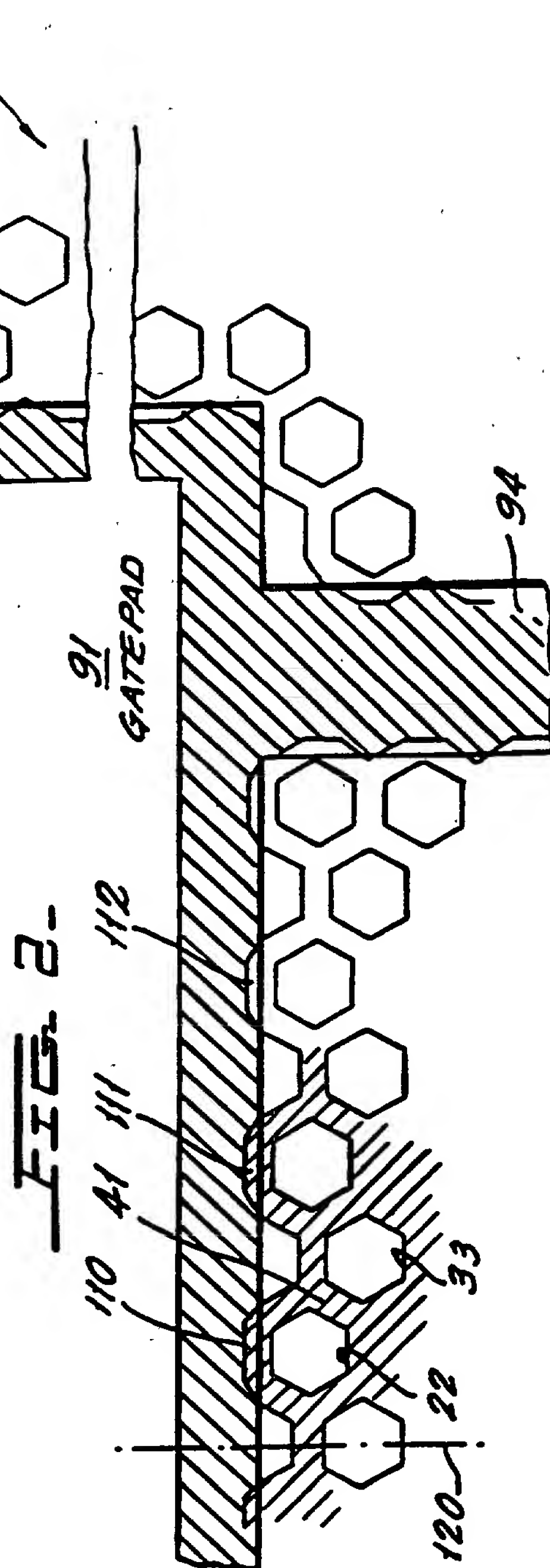
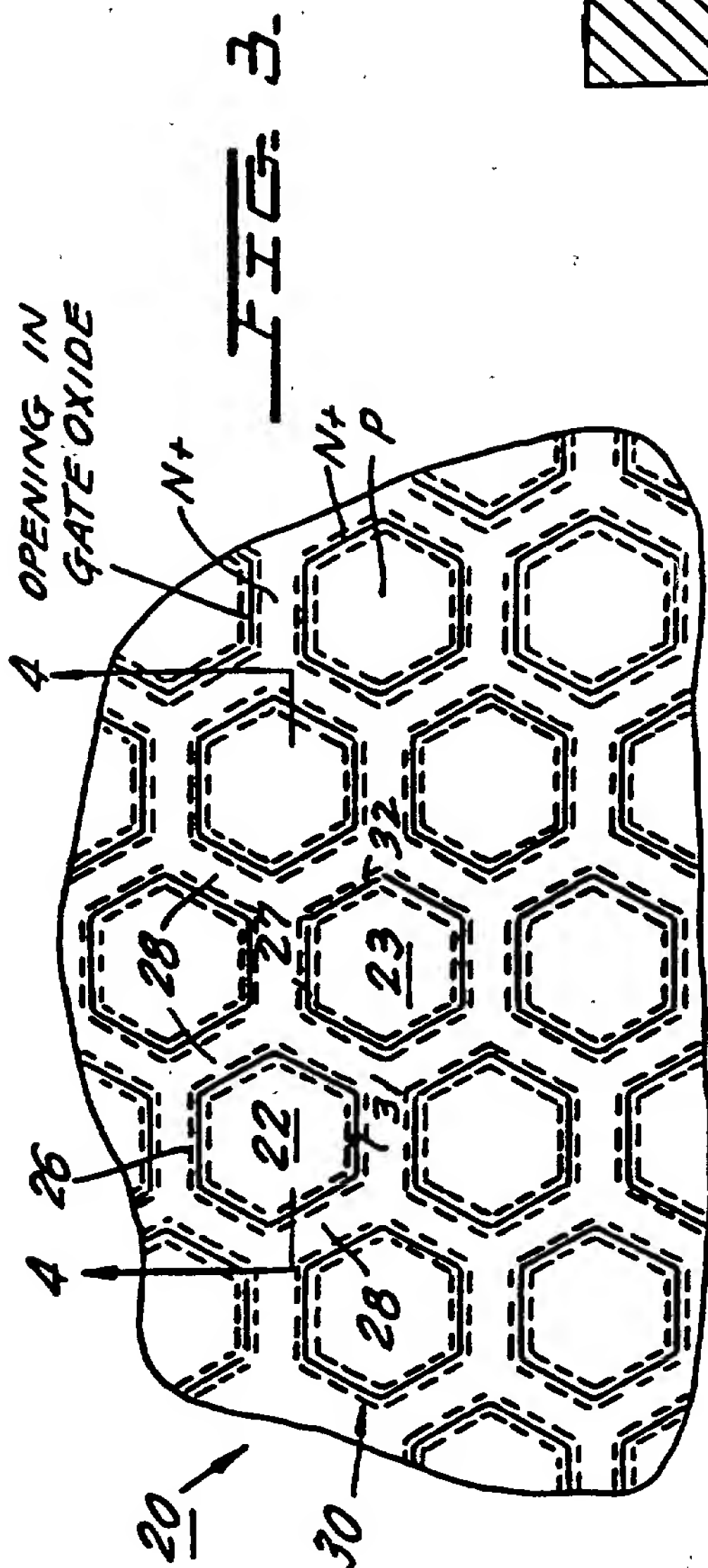


FIG. 4

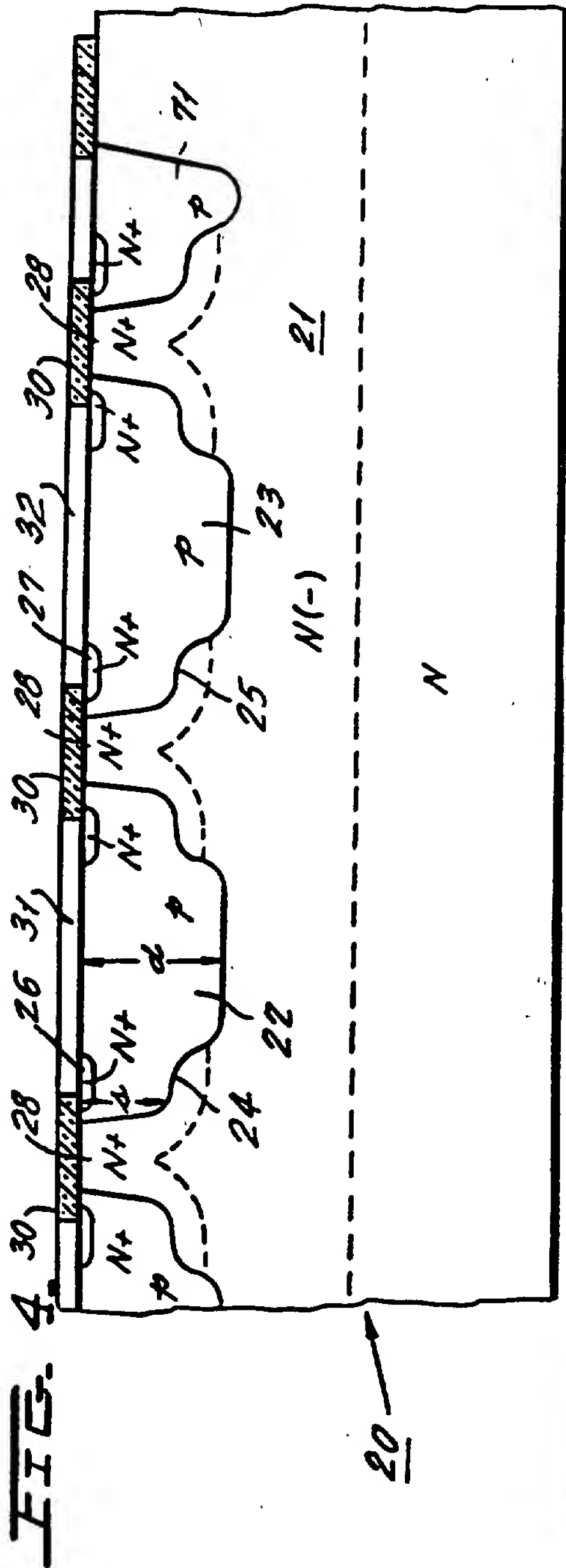
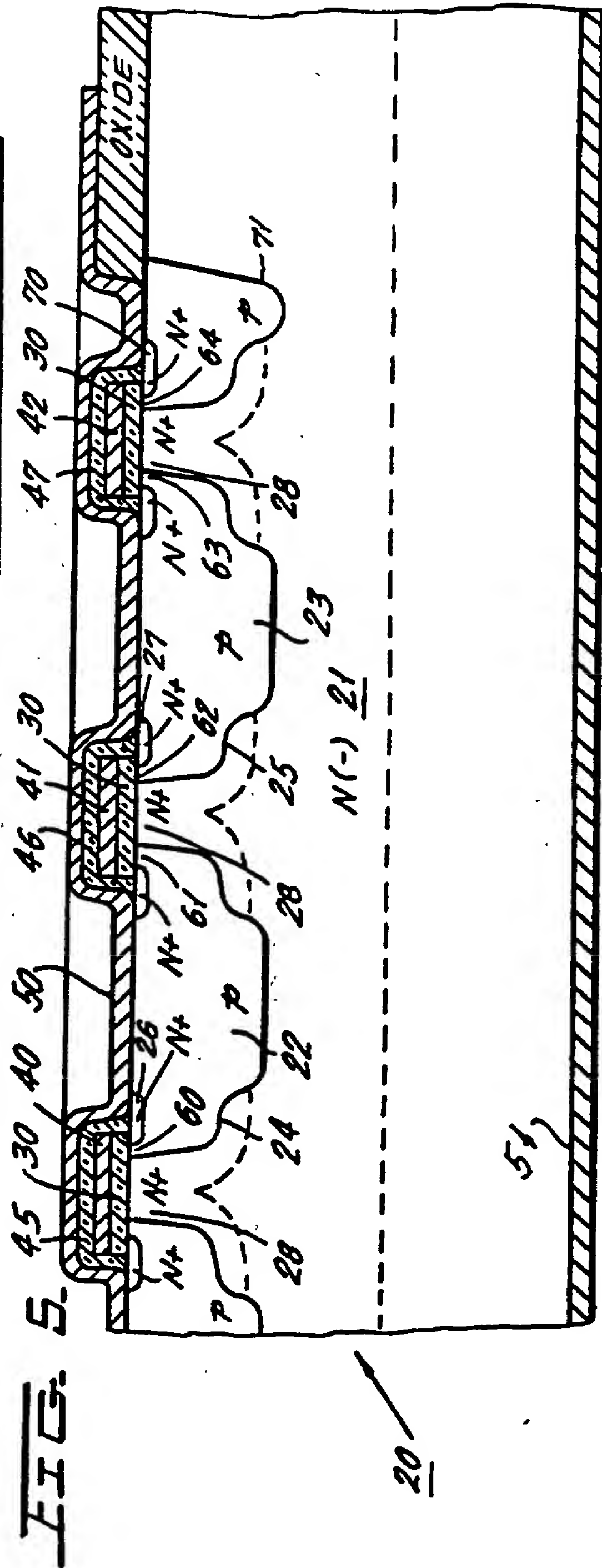


FIG. 5



PLURAL POLYGON SOURCE PATTERN FOR MOSFET

This is a continuation of application Ser. No. 07/291,423, filed Dec. 23, 1988, now U.S. Pat. No. 5,008,725, which, in turn, is a continuation of application Ser. No. 06/243,544, filed Mar. 13, 1981 (now abandoned) which, in turn, is a continuation of application Ser. No. 06/038,662, filed May 14, 1979 (now abandoned).

RELATED APPLICATIONS

This application is related to application Ser. No. 951,310, filed Oct. 13, 1978, now abandoned and refiled as continuation application Ser. No. 232,713, filed Feb. 9, 1981, now U.S. Pat. No. 4,376,286, entitled HIGH POWER MOSFET WITH LOW ON-RESISTANCE AND HIGH BREAKDOWN VOLTAGE, in the names of Alexander Lidow and Thomas Herman, and assigned to the assignee of the present invention.

BACKGROUND OF THE INVENTION

This invention relates to MOSFET devices, and more specifically relates to a novel source pattern for a MOSFET device of the type disclosed in above-mentioned U.S. Pat. No. 4,376,286 wherein a plurality of polygonal-shaped source elements are disposed over the surface of a semiconductor body and are spaced from one another by a closely controlled dimension.

High power MOSFETS having low on-resistance and high breakdown voltage are known and are shown in the above-noted U.S. Pat. No. 4,376,286. In the above application, the source electrodes are spaced, interdigitated source regions spaced from one another by two parallel channel regions covered by a common gate. The device has exceptionally low on-resistance along with the usual advantages of the MOSFET device over the bi-polar device particularly by virtue of a relatively high conductivity region disposed between the two adjacent channels and leading to a common drain electrode.

It has been found that an interdigitated structure has a relatively low packing density. Moreover, the interdigitated arrangement disclosed in the above U.S. Pat. No. 4,376,286 requires relatively complicated masks and has a relatively high capacitance.

BRIEF DESCRIPTION OF THE INVENTION

The present invention provides a novel high power MOSFET device with low forward resistance where, a very high packing density is available and which can be made with relatively simple masks. The device further has relatively low capacitance. Typically, the device may be made through the use of phosphorus implantation and D-MOS fabrication techniques but any desired technique can be used.

Each of the individual spaced source regions, in accordance with the invention, is polygonal in configuration and is preferably hexagonal to ensure a constant spacing along the major lengths of the sources disposed over the surface of the body. An extremely large number of small hexagonal source elements may be formed in the same surface of the semiconductor body for a given device. By way of example, 6,600 hexagonal source regions can be formed in a chip area having a dimension of about 100 by 140 mils to produce an effective

channel width of about 22,000 mils, thus permitting very high current capacity for the device.

The space between the adjacent sources may contain a polysilicon gate or any other gate structure where the gate structure is contacted over the surface of the device by elongated gate contact fingers which ensure good contact over the full surface of the device.

Each of the polygonal source regions is contacted by a uniform conductive layer which engages the individual polygonal sources through openings in an insulation layer covering the source regions, which openings can be formed by conventional D-MOS photolithographic techniques. A source pad connection region is then provided for the source conductor and a gate pad connection region is provided for the elongated gate fingers and a drain connection region is made to the reverse surface of the semiconductor device.

A plurality of such devices can be formed from a single semiconductor wafer and the individual elements can be separated from one another by scribing or any other suitable method.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of a completed element on a semiconductor wafer prior to the separation of the element away from the remainder of the wafer.

FIG. 2 is an enlarged detail of the gate pad to illustrate the relationship of the gate contact and the source polygons in the region of the gate pad.

FIG. 3 is a detailed plan view of a small portion of the source region during one stage of the manufacturing process of the device.

FIG. 4 is a cross-sectional view of FIG. 3 taken across the section line 4-4 in FIG. 3.

FIG. 5 is similar to FIG. 4 and shows the addition of a polysilicon gate, a source electrode means and drain electrode to the wafer.

DETAILED DESCRIPTION OF THE DRAWINGS

The polygon configuration of the source regions of the present invention is best shown in FIGS. 3, 4 and 5 which are first described.

Referring first to FIGS. 3 and 4, the device is shown prior to the application of the gate, source and drain electrodes. The manufacturing process can be of any desired type. The manufacturing process described in U.S. Pat. No. 4,376,286, referred to above, which is incorporated herein by reference, can be used whereby D-MOS fabrication techniques and ion implantation techniques can be advantageously employed for the formation of the junction and placement of the electrode in the most advantageous way.

The device is described as an N channel enhancement type device. It will be apparent that the invention will also apply to P channel devices and to depletion mode devices.

The device of FIGS. 3 and 4 has a plurality of polygonal source regions on one surface of the device, where these polygonal regions are preferably hexagonal in shape. Other shapes such as squares could have been used but the hexagonal shape provides better uniformity of spacing between adjacent source region perimeters.

In FIGS. 3 and 4, the hexagonal source regions are formed in a basic semiconductor body or wafer which can be an N type wafer of monocrystalline silicon which has a thin N-epitaxial region deposited thereon as best shown in FIG. 4. All junctions are

formed in epitaxial region 21. By using suitable masks, a plurality of P type regions such as regions 22 and 23 in FIGS. 3 and 4 are formed in one surface of the semiconductor wafer region 21, where these regions are generally polygonal in configuration and, preferably, are hexagonal.

A very large number of such polygonal regions are formed. For example, in a device having a surface dimension of 100 by 140 mils, approximately 6600 polygonal regions are formed to produce a total channel width of about 22,000 mils. Each of the polygonal regions may have a width measured perpendicular to two opposing sides of the polygon of about 1 mil or less. The regions are spaced from one another by a distance of about 0.6 mil when measured perpendicularly between the adjacent straight sides of adjacent polygonal regions.

The P+ regions 22 and 23 will have a depth d which is preferably about 5 microns to produce a high and reliable field characteristic. Each of the P regions has an outer shelf region shown as shelf regions 24 and 25 for P regions 22 and 23, respectively, having a depth s of about 1.5 microns. This depth should be as small as possible to reduce the capacitance of the device.

Each of the polygon regions including polygonal regions 22 and 23 receive N+ polygonal ring regions 26 and 27, respectively. Shelves 24 and 25 are located beneath regions 26 and 27, respectively. N+ regions 26 and 27 cooperate with a relatively conductive N+ region 28 which is the N+ region disposed between adjacent P type polygons to define the various channels between the source regions and a drain contact which will be later described.

The highly conductive N+ regions 28 are formed in the manner described in U.S. Pat. No. 4,376,286, referred to above, and are the subject of that application and produce a very low forward resistance for the device.

In FIGS. 3 and 4, it will be noted that the entire surface of the wafer is covered with an oxide layer or combined conventional oxide and nitride layers which are produced for the formation of the various junctions. This layer is shown as the insulation layer 30. The insulation layer 30 is provided with polygonal shaped openings such as openings 31 and 32 immediately above polygonal regions 22 and 23. Openings 31 and 32 have boundaries overlying the N+ type source rings 26 and 27 for the regions 22 and 23, respectively. The oxide strips 30, which remain after the formation of the polygonal shaped openings, define the gate oxide for the device.

Electrodes may then be applied to the device as shown in FIG. 5. These include a polysilicon grid which includes polysilicon sections 40, 41 and 42 which overlie the oxide sections 30.

A silicon dioxide coating is then deposited atop the polysilicon grid 40 shown as coating sections 45, 46 and 47 in FIG. 5 which insulates the polysilicon control electrode and the source electrode which is subsequently deposited over the entire upper surface of the wafer. In FIG. 5 the source electrode is shown as conductive coating 50 which may be of any desired material, such as aluminum. A drain electrode 51 is also applied to the device.

The resulting device of FIG. 5 is an N channel type device wherein channel regions are formed between each of the individual sources and the body of the semiconductor material which ultimately leads to the drain electrode 51. Thus, a channel region 60 is formed be-

tween the source ring 26, which is connected to source electrode 50, and the N+ region 28 which ultimately leads to the drain electrode 51. Channel 60 is inverted to N type conductivity upon the application of a suitable control voltage to the gate 40. In a similar manner, channels 61 and 62 are formed between the source region 26, which is connected to the conductor 50, and the surrounding N+ region 28 which leads to the drain 51. Thus, upon application of a suitable control voltage to the polysilicon gate (including finger 41 in FIG. 5), channels 61 and 62 become conductive to permit majority carrier conduction from the source electrode 50 to the drain 51. Note that channels labeled 60 and 61 of FIG. 5 are the same annular channel which is formed within the region 22. Similarly, channels 62 and 63 are the same annular channel formed in the region 23.

Each of the sources form parallel conduction paths where, for example, channels 63 and 64 beneath gate element 42 permit conduction from the source ring 27 and an N type source strip 70 to the N+ region 28 and then to the drain electrode 51.

It is to be noted that FIGS. 4 and 5 illustrate an end P type region 71 which encloses the edge of the wafer.

The contact 50 of FIG. 5 is preferably an aluminum contact. It will be noted that the contact region for the contact 50 lies entirely over and in alignment with the deeper portion of the P type region 22. This is done since it was found that aluminum used for the electrode 50 might spike through very thin regions of the P type material. Thus, one feature of the present invention is to ensure that the contact 50 lies principally over the deeper portions of the P regions such as P regions 22 and 23. This then permits the active channel regions defined by the annular shelves 24 and 25 to be as thin as desired in order to substantially reduce the device capacitance.

FIG. 1 illustrates one completed device using the polygonal source pattern of FIG. 5. The completed device shown in FIG. 1 is contained within the scribe regions 80, 81, 82 and 83 which enable the breaking out of a plurality of unitary devices each having a dimension of 100 by 140 mils from the body of the wafer.

The polygonal regions described are contained in a plurality of columns and rows. By way of example, the dimension A contains 65 columns of polygonal regions and may be about 83 mils. The dimension B may contain 100 rows of polygonal regions and may be about 148 mils. Dimension C, which is disposed between a source connection pad 90 and a gate connection pad 91, may contain 82 rows of polygonal elements.

The source pad 90 is a relatively heavy metal section which is directly connected to the aluminum source electrode 50 and permits convenient lead connection for the source.

The gate connection pad 91 is electrically connected to a plurality of extending fingers 92, 93, 94 and 95 which extend symmetrically over the outer surface of the area containing the polygonal regions and make electrical connection to the polysilicon gate as will be described in connection with FIG. 2.

Finally the outer circumference of the device contains the P+ (shown as "P" in the drawings) deep diffusion ring 71 which may be connected to a field plate 101 shown in FIG. 1.

FIG. 2 shows a portion of the gate pad 91 and the gate fingers 94 and 95. It is desirable to make a plurality of contacts to the polysilicon gate in order to reduce the R-C delay constant of the device. The polysilicon gate

has a plurality of regions including regions 110, 111, 112 and the like which extend outwardly and receive extensions of the gate pad and the gate pad elements 94 and 95. The polysilicon gate regions may be left exposed during the formation of the oxide coating 45-46-47 in FIG. 5 and are not coated by the source electrode 50. Note that in FIG. 2 the axis 120 is the axis of symmetry 120 which is that shown in FIG. 1.

Although the present invention has been described in connection with a preferred embodiment thereof, many variations and modifications will now become apparent to those skilled in the art. It is preferred, therefore, that the present invention be limited not by the specific disclosure herein, but only by the appended claims.

What is claimed is:

1. A high power MOSFET device having more than 1000 parallel-connected individual FET devices closely packed into a relatively small area comprising;

a thin wafer of semiconductor material having first and second spaced, parallel planar surfaces; at least a first portion of the thickness of said wafer which extends from said first planar surface consisting of an epitaxially deposited region of a first conductivity type;

a plurality of symmetrically disposed laterally distributed hexagonal base regions each having a second conductivity type formed in said epitaxially deposited region and extending for a given depth beneath said first planar surface;

said hexagonal base regions spaced at said first surface from surrounding ones by a symmetric hexagonal lattice of semiconductor material of said first conductivity type;

each side of each of said hexagonal base regions being parallel to an adjacent side of another of said hexagonal base regions;

a hexagonal annular source region of said first conductivity type formed in an outer peripheral region of each of said hexagonal base regions and extending downwardly from said first planar surface to a depth less than the depth of said base regions;

an outer rim of each of said annular source regions being radially inwardly spaced from an outer periphery of its respective hexagonal base region to form an annular channel between each of said outer rims of said annular source regions and said symmetric hexagonal lattice of semiconductor material of said first portion of said wafer;

a common source electrode formed on said first planar surface and connected to a plurality of said annular source regions and to interiorly adjacent surface areas of their said respective hexagonal base regions;

a drain electrode connected to said second planar surface of said wafer;

an insulation layer means on said first planar surface and overlying at least said annular channels;

a polysilicon gate electrode atop said insulation layer means and operable to invert said annular channels; and

a gate pad electrode section on the surface of said device and at least one finger extending from said gate pad; said at least one finger electrically contacting said polysilicon gate electrode at a plurality of spaced locations over the surface of said polysilicon gate electrode, thereby to reduce the R-C delay constant of said device.

2. The device of claim 1 wherein said annular channels have at least one leg in longitudinal alignment with other legs of other of said annular channels; said plurality of spaced locations disposed along a line defined by said legs of said annular channels which are in longitudinal alignment.

3. A high power MOSFET device having more than 1000 parallel-connected individual FET devices closely packed into a relatively small area comprising:

a thin wafer of semiconductor material having first and second spaced, parallel planar surfaces; at least a first portion of the thickness of said wafer which extends from said first planar surface consisting of an epitaxially deposited region of a first conductivity type;

a plurality of symmetrically disposed laterally distributed polygonal base regions each having a second conductivity type formed in said epitaxially deposited region and extending for given depth beneath said first planar semiconductor surface;

said polygonal base regions spaced at said first surface from surrounding ones by a symmetric polygonal lattice of semiconductor material of said first conductivity type;

each side of each of said polygonal base regions being parallel to an adjacent side of another of said polygonal base regions;

a polygonal annular source region of said first conductivity type formed in an outer peripheral region of each of said polygonal base regions and extending downwardly from said first planar surface to a depth less than the depth of said base regions;

an outer rim of each of said annular source regions being radially inwardly spaced from an outer periphery of its respective polygonal base region to form an annular channel between each of said outer rims of said annular source regions and said symmetric polygonal lattice of semiconductor material of said first portion of said wafer;

a common source electrode formed on said first planar surface and connected to a plurality of said annular source regions and to interiorly adjacent surface areas of their said respective polygonal base regions;

a drain electrode connected to said second planar semiconductor surface of said wafer;

an insulation layer means on said first planar surface and overlying at least said annular channels;

a polysilicon gate electrode atop said insulation layer means and operable to invert said annular channels; and

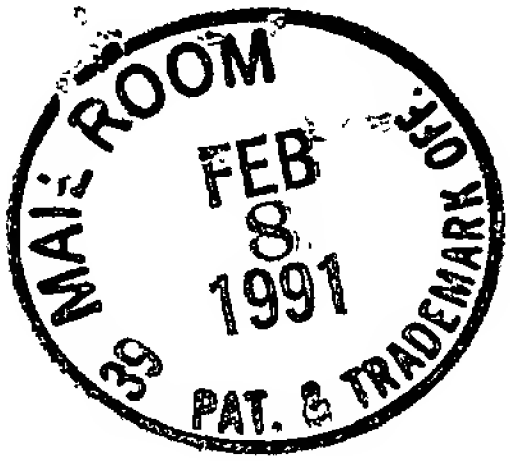
a gate pad electrode section on the surface of said device and at least one finger extending from said gate pad; said at least one finger electrically contacting said polysilicon gate electrode at a plurality of spaced locations over the surface of said polysilicon gate electrode, thereby to reduce the R-C delay constant of said device.

4. The device of claim 3 wherein said annular channels have at least one leg in longitudinal alignment with other legs of other of said annular channels; said plurality of spaced locations disposed along a line defined by said legs of said annular channels which are in longitudinal alignment.

5. A vertical conduction high power MOSFET device exhibiting relatively low on-resistance and relatively high breakdown voltage; said device comprising;

- a wafer of semiconductor material having planar first and second opposing semiconductor surface; said wafer of semiconductor material having a relatively lightly doped major body portion for receiving junctions and being doped with impurities of a first conductivity type; 5
- a plurality of highly packed, equally spaced symmetrically disposed identical polygonal base regions of a second conductivity type formed in said wafer, each extending from said first planar semiconductor surface to a first depth beneath said first planar semiconductor surface; said polygonal base regions spaced from surrounding ones by a symmetric polygonal lattice of semiconductor material of said first conductivity type; the space between adjacent ones of said polygonal base regions defining a common conduction region of said first conductivity type extending downwardly from said first planar semiconductor surface; 10
- a respective polygonal annular source region of said first conductivity type formed within each of said polygonal base regions and extending downwardly from said first planar semiconductor surface to a depth less than said first depth; each of said polygonal annular source regions being laterally spaced along said first planar semiconductor surface from the facing respective edges of said common conduction region thereby to define respective coplanar annular channel regions along said first planar semiconductor surface between the polygonal sides of each of said polygonal annular source regions and said common conduction region; 15
- a common source electrode means connected to said polygonal annular source regions and their respective base regions; 20
- gate insulation layer means on said first planar semiconductor surface, disposed at least on said coplanar channel regions; 25
- gate electrode means on said gate insulation layer means and overlying said coplanar channel regions; 30
- a drain conductive region remote from said common conduction region and separated therefrom by said relatively lightly doped major body portion and extending to said second semiconductor surface; 35
- a drain electrode coupled to said drain conductive region; and 40
- a gate pad electrode section on the surface of said device and at least one finger extending from said gate pad; said at least one finger electrically contacting said polysilicon gate electrode at a plurality of spaced locations over the surface of said polysilicon gate electrode, thereby to reduce the R-C delay constant of said device. 45
6. The device of claim 5 wherein said annular channels have at least one leg in longitudinal alignment with other legs of other of said annular channels; said plurality of spaced locations disposed along a line defined by said legs of said annular channels which are in longitudinal alignment. 50
7. A high power MOSFET device exhibiting relatively low on-resistance and relatively high breakdown voltage; said device comprising:
- a wafer of semiconductor material having planar first and second opposing semiconductor surfaces; said 55

- wafer of semiconductor material having a relatively lightly doped major body portion for receiving junctions and being doped with impurities of a first conductivity type;
- at least first and second spaced base regions of a second conductivity type formed in said wafer and extending downwardly from said first planar semiconductor surface to a first depth beneath said first planar semiconductor surface; the space between said at least first and second spaced base regions defining a common conduction region of a first conductivity type at a given first planar semiconductor surface location; said common conduction region extending downwardly from said first planar semiconductor surface;
- first and second annular source regions of said first conductivity type formed in said first and second spaced base regions respectively at said first planar semiconductor surface locations to a depth less than said first depth; said first and second annular source regions being laterally spaced along said first planar semiconductor surface from the facing respective edges of said common conduction region thereby to define first and second channel regions along said first planar semiconductor surface between each pair of said first and second annular source regions, respectively, and said common conduction region; each of said first and second channel regions being coplanar with one another;
- a common source electrode means connected to said first and second annular source regions and their respective first and second base regions;
- gate insulation layer means on said first planar semiconductor surface, disposed at least on said first and second channel regions;
- gate electrode means on said gate insulation layer means and overlying said first and second channel regions;
- a drain conductive region remote from said common conduction region and separated therefrom by said relatively lightly doped major body portion and extending to said second semiconductor surface;
- a drain electrode coupled to said drain conductive region;
- each of said at least first and second spaced base regions having a polygonal configuration; each of said first and second annular source regions having a polygonal configuration conforming to that of their respective base region; and
- a gate pad electrode section on the surface of said device and at least one finger extending from said gate pad; said at least one finger electrically contacting said polysilicon gate electrode at a plurality of spaced locations over the surface of said polysilicon gate electrode, thereby to reduce the R-C delay constant of said device.
8. The device of claim 7 wherein said annular channels have at least one leg in longitudinal alignment with other legs of other of said annular channels; said plurality of spaced locations disposed along a line defined by said legs of said annular channels which are in longitudinal alignment. 60
- * * * * *



OFGS File: IR-1013(Cont). (2-563)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:

Alexander Lidow et al

Date: February 8, 1991

Serial No.:

Filed:

For: PLURAL POLYGON SOURCE PATTERN FOR MOSFET

Hon. Commissioner of Patents and Trademarks
Washington, DC 20231

REQUEST FOR CONTINUING APPLICATION UNDER 37 C.F.R. §1.60

Sir:

This is a request for the filing of a Continuation application under the provisions of 37 C.F.R. §1.60 of pending application Serial No. 07/291,423, filed December 23, 1988, by Alexander Lidow, Thomas Herman and Vladimir Rodov, entitled PLURAL POLYGON SOURCE PATTERN FOR MOSFET.

Enclosed is a copy of the prior application, including the oath or declaration as originally filed.

I hereby verify that the attached papers are a true copy of prior application Serial No. 07/291,423, filed December 23, 1988 and further that this statement is made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Cancel in this application original claims 2-11 of the prior application before calculating the filing fee.

The filing fee is calculated as follows:

BASIC Filing Fee:	\$ 630.00
Number of Claims in Excess of 20: ____ x \$20	
Number of Independent Claims over 3: ____ x \$60	
One or more multiple dependent claims:	\$ _____
TOTAL FILING FEE:	<u>\$ 630.00</u>

OR:

TOTAL FILING FEE REDUCED 50% FOR SMALL ENTITY	<u>\$ _____</u>
-----------------------------------------------------	-----------------

Check No. 019664 which includes the amount of \$630.00 in payment of the filing fee is enclosed herewith.

The Patent and Trademark Office is hereby authorized to charge any additional fees or credit any refund, at any time during the prosecution of this application, to Deposit Account No. 15-0700. A duplicate copy of this Request is submitted for this purpose.

Amend the specification by inserting at page 1, before line 1, the paragraph:

--This is a continuation of application Serial No. 07/291,423, filed December 23, 1988 which, in turn, is a continuation of application Serial No. 06/243,544, filed March 13, 1981 (now abandoned) which, in turn, is a continuation of application Serial No. 06/038,662, filed May 14, 1979 (now abandoned).--

Informal drawings accompany the filing of this application. Formal drawings will be submitted at a later date.

The original prior application was assigned to International Rectifier Corporation and is recorded at Reel 3657, Frame 945.

The power of attorney in the original prior application, as originally filed, is to OSTROLENK, FABER, GERB & SOFFEN, 1180 Avenue of the Americas, New York, New York 10036-8403, and the members of the firm: Marvin C. Soffen, Reg. No. 17,542; Samuel H. Weiner, Reg. No. 18,510; Jerome H. Berliner, Reg. No. 18,653; Robert C. Faber, Reg. No. 24,322; Edward A. Meilman, Reg. No. 24,735 and Stanley H. Lieberstein, Reg. No. 22,400, as attorneys with full power of substitution and revocation to prosecute this application, to transact all business in the Patent and Trademark Office in connection therewith and to receive all correspondence.

SEND CORRESPONDENCE TO:

DIRECT TELEPHONE CALLS TO:

OSTROLENK, FABER, GERB & SOFFEN
1180 Avenue of the Americas
New York, New York 10036-8403

(212) 382-0700

The Power appears in the original papers in the prior application.

EXPRESS MAIL CERTIFICATE

I hereby certify that this correspondence is being deposited with the United States Postal Service as Express Mail Post Office to Addressee (mail label #B68500860) in an envelope addressed to: Commissioner of Patents and Trademarks, Washington, DC, 20231, on February 8, 1991

Name of Person mailing Correspondence



Signature

February 8, 1991

Date of Signature

SHW:ir

Respectfully submitted,



Samuel H. Weiner
Registration No.: 18,510
OSTROLENK, FABER, GERB & SOFFEN
1180 Avenue of the Americas
New York, New York 10036-8403
Telephone: (212) 382-0700



653 017

IR-674

PLURAL POLYGON SOURCE PATTERN FOR MOSFET

ABSTRACT OF THE DISCLOSURE

A high power MOSFET has a plurality of closely packed polygonal sources spaced from one another on one surface of a semiconductor body. An elongated gate electrode is exposed in the spacing between the polygonal sources and cooperates with two channels, one for each adjacent source electrode, to control conduction from the source electrode through the channel and then to a drain electrode on the opposite surface of the semiconductor body. The conductive region adjacent the channel and between adjacent sources is relatively highly conductive in the section of the channel adjacent to the surface containing the sources. The polygonal shaped source members are preferably hexagonal so that the distances between adjacent sources is relatively constant throughout the device. Each polygonal region has a relatively deep central portion and a shallow outer shelf portion. The shelf portion generally underlies an annular source region. The deep central portion underlies an aluminum conductive electrode and is sufficiently deep that it will not be fully penetrated by aluminum spiking.

DISSEMINATED



insert
at

- 1 -

IR-674

PLURAL POLYGON SOURCE PATTERN FOR MOSEET

SU, CL RELATED APPLICATIONS

P

This application is related to ~~co~~pending application (Serial) No. 951,310 (IR-664), filed October 13, 1978, entitled HIGH POWER MOSFET WITH LOW ON-RESISTANCE AND HIGH BREAKDOWN VOLTAGE, in the names of Alexander Lidow and Thomas Herman, and assigned to the assignee of the present invention.

CL

BACKGROUND OF THE INVENTION

P

This invention relates to MOSFET devices, and more specifically relates to a novel source pattern for a MOSFET device of the type disclosed in above-mentioned ~~co~~pending application Serial No. 951,310 wherein a plurality of polygonal-shaped source elements are disposed over the surface of a semiconductor body and are spaced from one another by a closely controlled dimension.

High power MOSFETS having low on-resistance and high breakdown voltage are known and are shown in the above-noted ~~co~~pending application Serial No.

951,310. In the above application, the source electrodes are spaced, interdigitated source regions spaced

from one another by two parallel channel regions covered by a common gate. The device has exceptionally low on-resistance along with the usual advantages of the MOSFET device over the bi-polar device particularly by virtue of a relatively high conductivity region disposed between the two adjacent channels and leading to a common drain electrode.

It has been found that an interdigitated structure has a relatively low packing density. Moreover, the interdigitated arrangement disclosed in the above application Serial No. 951,310 requires relatively complicated masks and has a relatively high capacitance.

BRIEF DESCRIPTION OF THE INVENTION

The present invention provides a novel high power MOSFET device with low forward resistance where, however, a very high packing density is available and which can be made with relatively simple masks. The device further has relatively low capacitance. Typically, the device may be made through the use of phosphorus implantation and D-MOS fabrication techniques but any desired technique can be used.

Each of the individual spaced source regions, in accordance with the invention, is polygonal in configuration and is preferably hexagonal to ensure a constant spacing along the major lengths of the sources disposed over the surface of the body. An extremely large number of small hexagonal source elements may be formed in the same surface of the semiconductor body for a given device. By way of example, 6,600 hexagonal source regions can be formed in a chip area

β having a dimension of about 100 by 140 mils to produce
L an effective channel width of about 22,000 mils, thus
permitting very high current capacity for the device.

The space between the adjacent sources may
5 contain a polysilicon gate or any other gate structure
where the gate structure is contacted over the surface
of the device by elongated gate contact fingers which
ensure good contact over the full surface of the device.

Each of the polygonal source regions is
10 contacted by a uniform conductive layer which engages
the individual polygonal sources through openings
in an insulation layer covering the source regions,
which openings can be formed by conventional D-MOS
photolithographic techniques. A source pad connection
15 region is then provided for the source conductor and a
gate pad connection region is provided for the elon-
gated gate fingers and a drain connection region is
made to the reverse surface of the semiconductor device.

A plurality of such devices can be formed
20 from a single semiconductor wafer and the individual
elements can be separated from one another by scribing
or any other suitable method.

DR CL BRIEF DESCRIPTION OF THE DRAWINGS ✓

P Figure 1 is a plan view of a completed element
25 on a semiconductor wafer prior to the separation of the
element away from the remainder of the wafer.

Figure 2 is an enlarged detail of the gate pad to
illustrate the relationship of the gate contact and the
source polygons in the region of the gate pad.

30 Figure 3 is a detailed plan view of a small
portion of the source region during one stage of the
manufacturing process of the device.

Figure 4 is a cross-sectional view of Figure
3 taken across the section line 4-4 in Figure 3.

Figure 5 is similar to Figure 4 and shows the addition of a polysilicon gate, a source electrode means and drain electrode to the wafer.

DE, CL DETAILED DESCRIPTION OF THE DRAWINGS

5 P The polygon configuration of the source regions of the present invention is best shown in Figures 3, 4 and 5 which are first described.

Referring first to Figures 3 and 4, the device is shown prior to the application of the gate, source and drain electrodes. The manufacturing process can be of any desired type. The manufacturing process described in ~~U.S. Patent 4,376,286, referred to above~~ ^{U.S. Patent 4,376,286, referred to above} ~~in pending application Serial No. 951,310,~~ which is incorporated herein by reference, can be used whereby D-MOS fabrication techniques and ion implantation techniques can be advantageously employed for the formation of the junction and placement of the electrode in the most advantageous way.

20 The device is described as an N channel enhancement type device. It will be apparent that the invention will also apply to P channel devices and to depletion mode devices.

The device of Figures 3 and 4 has a plurality of polygonal source regions on one surface of the device, where these polygonal regions are preferably hexagonal in shape. Other shapes such as squares could have been used but the hexagonal shape provides better uniformity of spacing between adjacent source region perimeters.

30 In Figures 3 and 4, the hexagonal source regions are formed in a basic semiconductor body or wafer which can be an N type wafer 20 of monocrystalline silicon which has a thin N- epitaxial region 21 deposited thereon as best shown in Figure 4. All junctions are formed in epitaxial region 21. By using suitable masks, a plurality of P type regions such as regions 22

and 23 in Figures 3 and 4 are formed in one surface of the semiconductor wafer region 21, where these regions are generally polygonal in configuration and, preferably, are hexagonal.

5 A very large number of such polygonal regions are formed. For example, in a device having a surface
B dimension of 100 by 140 mils, approximately 6600 poly-
gonal regions are formed to produce a total channel
B width of about 22,000 mils. Each of the polygonal
10 regions may have a width measured perpendicular to two
opposing sides of the polygon of about 1 mil or less.
The regions are spaced from one another by a distance
B of about 0.6 mil when measured perpendicularly between
the adjacent straight sides of adjacent polygonal
15 regions.

The P+ regions 22 and 23 will have a depth d
B which is preferably about 5 microns to produce a high
and reliable field characteristic. Each of the P
regions has an outer shelf region shown as shelf regions
20 24 and 25 for P regions 22 and 23, respectively, having
a depth s of about 1.5 microns. This ^{depth} ~~distance~~ should
be as small as possible to reduce the capacitance of
the device.

Each of the polygon regions including polygonal
25 regions 22 and 23 receive N+ polygonal ring regions 26
and 27, respectively. Shelves 24 and 25 are located
beneath regions 26 and 27, respectively. N+ regions
26 and 27 cooperate with a relatively conductive N+
region 28 which is the N+ region disposed between
30 adjacent P type polygons to define the various channels
between the source regions and a drain contact which
will be later described.

The highly conductive N+ regions 28 are
formed in the manner described in ~~above noted copending~~
a U.S. Patent 4,376,286, referred to above,
a B 35 application Serial No. 951,310 and are the subject of
No. 1

7

that application and produce a very low forward resistance for the device.

In Figures 3 and 4, it will be noted that the entire surface of the wafer is covered with an oxide layer or combined conventional oxide and nitride layers which are produced for the formation of the various junctions. This layer is shown as the insulation layer 30. The insulation layer 30 is provided with polygonal shaped openings such as openings 31 and 32 immediately above polygonal regions 22 and 23. Openings 31 and 32 have boundaries overlying the N+ type source rings 26 and 27 for the regions 22 and 23, respectively. The oxide strips 30, which remain after the formation of the polygonal shaped openings, define the gate oxide for the device.

Electrodes may then be applied to the device as shown in Figure 5. These include a polysilicon grid which includes polysilicon sections 40, 41 and 42 which overlie the oxide sections 30.

A silicon dioxide coating is then deposited atop the polysilicon grid 40 shown as coating sections 45, 46 and 47 in Figure 5 which insulates the polysilicon control electrode and the source electrode which is subsequently deposited over the entire upper surface of the wafer. In Figure 5 the source electrode is shown as conductive coating 50 which may be of any desired material, such as aluminum. A drain electrode 51 is also applied to the device.

The resulting device of Figure 5 is an N channel type device wherein channel regions are formed between each of the individual sources and the body of the semiconductor material which ultimately leads to the drain electrode 51. Thus, a channel region 60 is formed between the source ring 26, which is connected

07653017-1000004

a
to source electrode 50, and the N+ region 28 which ultimately leads to the drain electrode 51. Channel 60 is inverted to ~~the~~ N type conductivity upon the application of a suitable control voltage to the gate 40.

5 In a similar manner, channels 61 and 62 are formed between the source region 26, which is connected to the conductor 50, and the surrounding N+ region 28 which leads to the drain 51. Thus, upon application of a suitable control voltage to the polysilicon gate (including finger 41 in Figure 5), channels 61 and 62 become
10 conductive to permit majority carrier conduction from the source electrode 50 to the drain 51. β'

Instr. B1
p Each of the sources form parallel conduction paths where, for example, channels 63 and 64 beneath
15 gate element 42 permit conduction from the source ring 27 and an N type source strip 70 to the N+ region 28 and then to the drain electrode 51.

It is to be noted that Figures 4 and 5 illustrate an end P type region 71 which encloses the edge
20 of the wafer.

a
The contact 50 of Figure 5 is preferably an aluminum contact. It will be noted that the contact region for the contact ⁵⁰55 lies entirely over and in alignment with the deeper portion of the P type region
25 22. This is done since it was found that aluminum used for the electrode 50 might spike through very thin regions of the P type material. Thus, one feature of the present invention is to ensure that the contact 50 lies principally over the deeper portions of the P
30 regions such as P regions 22 and 23. This then permits the active channel regions defined by the annular shelves 24 and 25 to be as thin as desired in order to substantially reduce the device capacitance.

Figure 1 illustrates one completed device
35 using the polygonal source pattern of Figure 5. The completed device shown in Figure 1 is contained within

9

the scribe regions 80, 81, 82 and 83 which enable the breaking out of a plurality of unitary devices each having a dimension of 100 by 140 mils from the body of the wafer.

5 The polygonal regions described are contained in a plurality of columns and rows. By way of example, the dimension A contains 65 columns of polygonal regions and may be about 83 mils. ^B The dimension B may contain 100 rows of polygonal regions and may be about 148 ^B mils. Dimension C, which is disposed between a source connection pad 90 and a gate connection pad 91, may contain 82 rows of polygonal elements.

10 ^B The source pad 90 is a relatively heavy metal section which is directly connected to the aluminum source electrode 50 and permits convenient lead connection for the source.

15 The gate connection pad 91 is electrically connected to a plurality of extending fingers 92, 93, 94 and 95 which extend symmetrically over the outer surface of the area containing the polygonal regions and make electrical connection to the polysilicon gate as will be described in connection with Figure 2.

20 Finally the outer circumference of the device contains the P+ ^(shown as "P" in the drawings) deep diffusion ring 71 which may be connected to a field plate 101 shown in Figure 1.

25 Figure 2 shows a portion of the gate pad 91 and the gate fingers 94 and 95. It is desirable to make a plurality of contacts to the polysilicon gate in order to reduce the R-C delay constant of the device. The polysilicon gate has a plurality of regions including regions 110, 111, 112 and the like which extend outwardly and receive extensions of the gate pad and the gate pad elements 94 and 95. The polysilicon gate regions may be left exposed during the formation of the oxide coating 45-46-47 in Figure 5 and are not coated by the source electrode 50. Note that in Figure 2 the axis 120 is the axis of symmetry 120

10

which is that shown in Figure 1.

Although the present invention has been described in connection with a preferred embodiment thereof, many variations and modifications will now
5 become apparent to those skilled in the art. It is preferred, therefore, that the present invention be limited not by the specific disclosure herein, but only by the appended claims.

11

CM WHAT IS CLAIMED IS:

1. A high power MOSFET device; said device comprising a wafer of semiconductor material having a first surface and a parallel second surface; said first surface having a plurality of equally spaced symmetrically disposed polygonal source regions; a gate insulation layer on said first surface and disposed between said source regions; and a gate electrode on said gate insulation layer; a drain electrode on said second surface; and source electrode means connected to said polygonal source regions; a ring-shaped channel means of a first of the conductivity types disposed around the outer periphery of each of said polygonal source regions and beneath said gate insulation layer; one end of each of said channels being electrically connected to said source electrode means; the opposite end of each of said channels connected to respective regions which are centrally disposed beneath said gate insulation layer and which has the second of the conductivity types; a relatively high resistivity region of the second of the conductivity types underlying said common region and being continuous with said common region; said common region having a substantially higher conductivity than said underlying region; said common region and said underlying region being in series in the current path from said first and second source electrode means to said drain electrode.

2. The device of claim 1 wherein each of said source regions is hexagonal.

3. The device of claim 1 or 2 wherein each of said polygonal source regions has a relatively deep central region and a relatively shallow outer region; said relatively deep central region underlying said source electrode means.

5

10

15

20

25

5

12

4. A MOSFET device formed by D-MOS manufacturing techniques comprising, in combination:

a semiconductor chip;

5 a plurality of symmetrically disposed, polygonal source regions disposed on one surface of said chip and source electrode means connected to said source regions;

10 a gate electrode disposed between said spaced source regions and disposed on an insulation layer on top of said chip;

15 first and second channels disposed between the adjacent sides of each of said source regions and capable of being inverted by a gate bias; said first and second channels having spaced ends which extend into common respective semiconductor regions beneath said gate insulation layer; the opposite ends of said first and second channels connected to said source electrode means;

20 said first and second channels being of a first conductivity type and being capable of inversion to said second conductivity type; said common semiconductor region defining a current path across the thickness of said chip and having a high conductivity adjacent said surface of said chip and a low
25 conductivity necessary for reverse voltage withstand ability at a depth greater than about one micron below said surface;

30 whereby said high conductivity region of said common region substantially decreases the on-resistance of said device.

5. The device of claim 4 wherein said chip has a bottom surface; said bottom surface having a drain electrode connected thereto.

6. The MOSFET of claim 5 wherein said first and second channels are the end regions of

5 respective relatively deep regions which extend away from one another and which have large outer radii of curvature.

7. The device of claim 4, 5 or 6 wherein said source regions are hexagonal.

8. The device of claim 1 or 4 wherein there are in excess of about 1,000 polygon source regions each having a width of about 1 mil.

9. The device of claim 8 wherein said source regions are hexagonal.

10. The device of claim 1 or 4 wherein each of said polygonal source regions has a width of about 1 mil.

11. The device of claim 8 wherein each of said polygon source regions has a width of about 1 mil.

07653447-126394

add
a3

UNITED STATES OF AMERICA
COMBINED DECLARATION AND POWER OF ATTORNEY
FOR PATENT APPLICATION

OFGS FILE NO.
IR-674

As a below named inventor, I hereby declare that: my residence, post office address and citizenship are as stated below next to my name; that I verily believe that I am the original, first and sole inventor (if only one name is listed below) or a joint inventor (if plural inventors are named) of the invention entitled:

PLURAL POLYGON SOURCE PATTERN FOR MOSFET

described and claimed:

☒ in the attached specification,

☐ in United States patent Application Serial Number _____ filed _____

that I understand the content thereof, that I do not know and do not believe the same was ever known or used in the United States of America before my or our invention thereof, or patented or described in any printed publication in any country before my or our invention thereof or more than one year prior to this application, that the same was not in public use or on sale in the United States of America more than one year prior to this application, that the invention has not been patented or made the subject of an inventor's certificate issued before the date of this application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than twelve months prior to this application, that I acknowledge my duty to disclose information of which I am aware which is material to the examination of this application, and that no application for patent or inventor's certificate on this invention has been filed in any country foreign to the United States of America prior to this application by me or my legal representatives or assigns, except as follows:

COUNTRY	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 35 U.S.C. 119
			YES _____ NO _____
			YES _____ NO _____

☐ CONTINUED ON PAGE 2

I hereby appoint OSTROLENK, FABER, GERB & SOFFEN and the members of the Firm, Sidney G. Faber-Reg. No. 14,521; Bernard Gerb- Reg. No. 17,224; Marvin C. Soffen- Reg. No. 17,542; Samuel H. Weiner- Reg. No. 18,510; Jerome M. Berliner- Reg. No. 18,653; Robert C. Faber- Reg. No. 24,322; Edward A. Meilman- Reg. No. 24,735 and Stanley H. Lieberstein- Reg. No. 22,400, as attorneys with full power of substitution and revocation to prosecute this application, to transact all business in the Patent & Trademark Office connected therewith and to receive all correspondence.

SEND CORRESPONDENCE TO:

OSTROLENK, FABER, GERB & SOFFEN
260 Madison Avenue, New York, New York 10016

DIRECT TELEPHONE CALLS TO:

(212) 685-8470

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful statements may jeopardize the validity of the application or any patent issued thereon.

FULL NAME OF SOLE OR FIRST INVENTOR <u>Alexander Lidow</u> 40100		INVENTOR'S SIGNATURE <u>[Signature]</u>	DATE 4/30/79
RESIDENCE 4005 Strand Avenue		CITIZENSHIP U.S.A.	
POST OFFICE ADDRESS Manhattan Beach, California 90266 CA			
FULL NAME OF SECOND JOINT INVENTOR, IF ANY <u>Thomas Herman</u> 40200		INVENTOR'S SIGNATURE <u>[Signature]</u>	DATE 4/30/79
RESIDENCE 1622 Herrin Drive		CITIZENSHIP U.S.A.	
POST OFFICE ADDRESS Redondo Beach, California 90278 CA			
FULL NAME OF THIRD JOINT INVENTOR, IF ANY <u>Vladimir Rumennik</u> 40300		INVENTOR'S SIGNATURE <u>[Signature]</u>	DATE 4.30.79
RESIDENCE 717 Indiana Court		CITIZENSHIP Stateless	
POST OFFICE ADDRESS El Segundo, California 90245 CA			

☐ CONTINUED ON PAGE 2

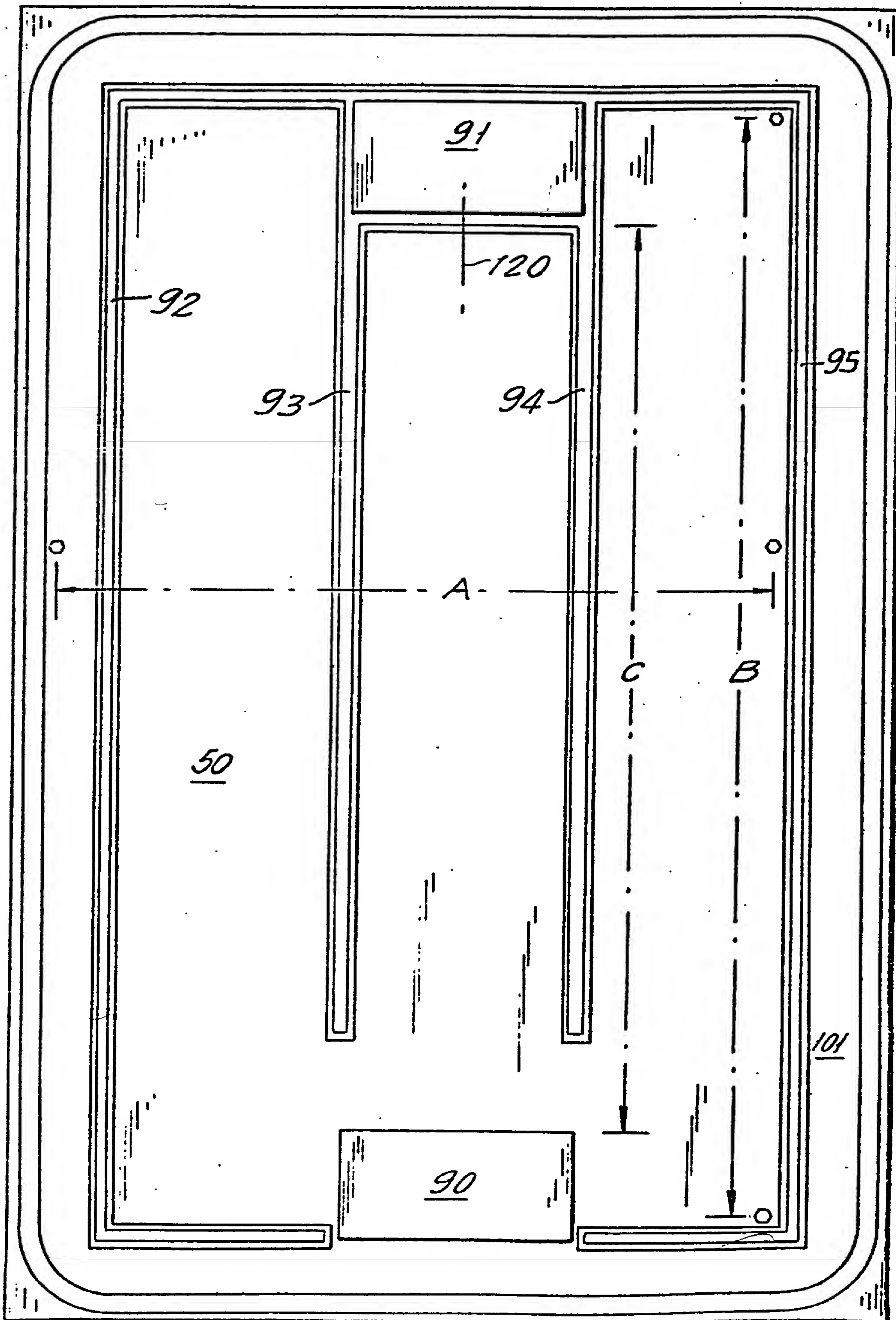
20

FIG. 1

83

FIG. 2

80



83

51

FIG. 1

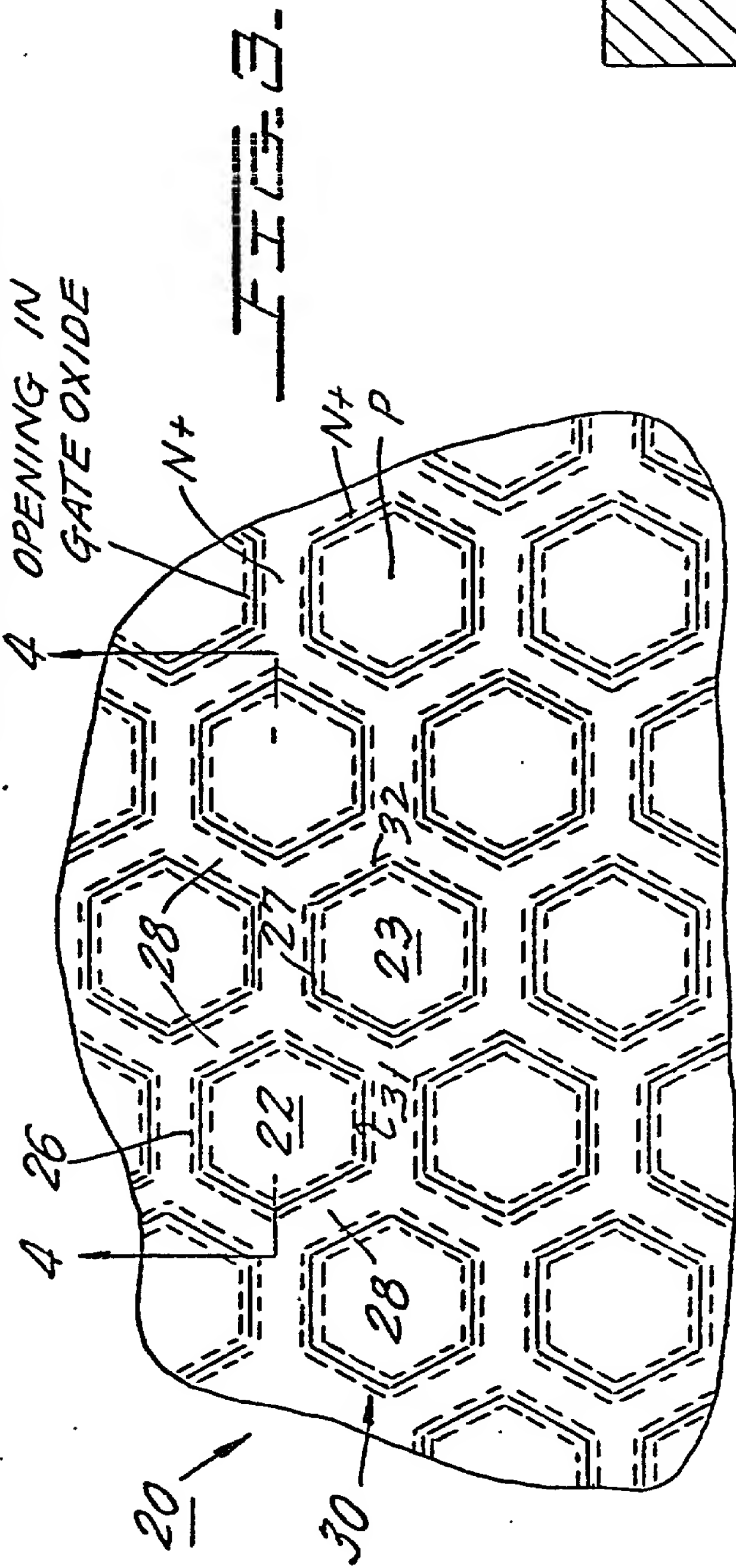


FIG. 2

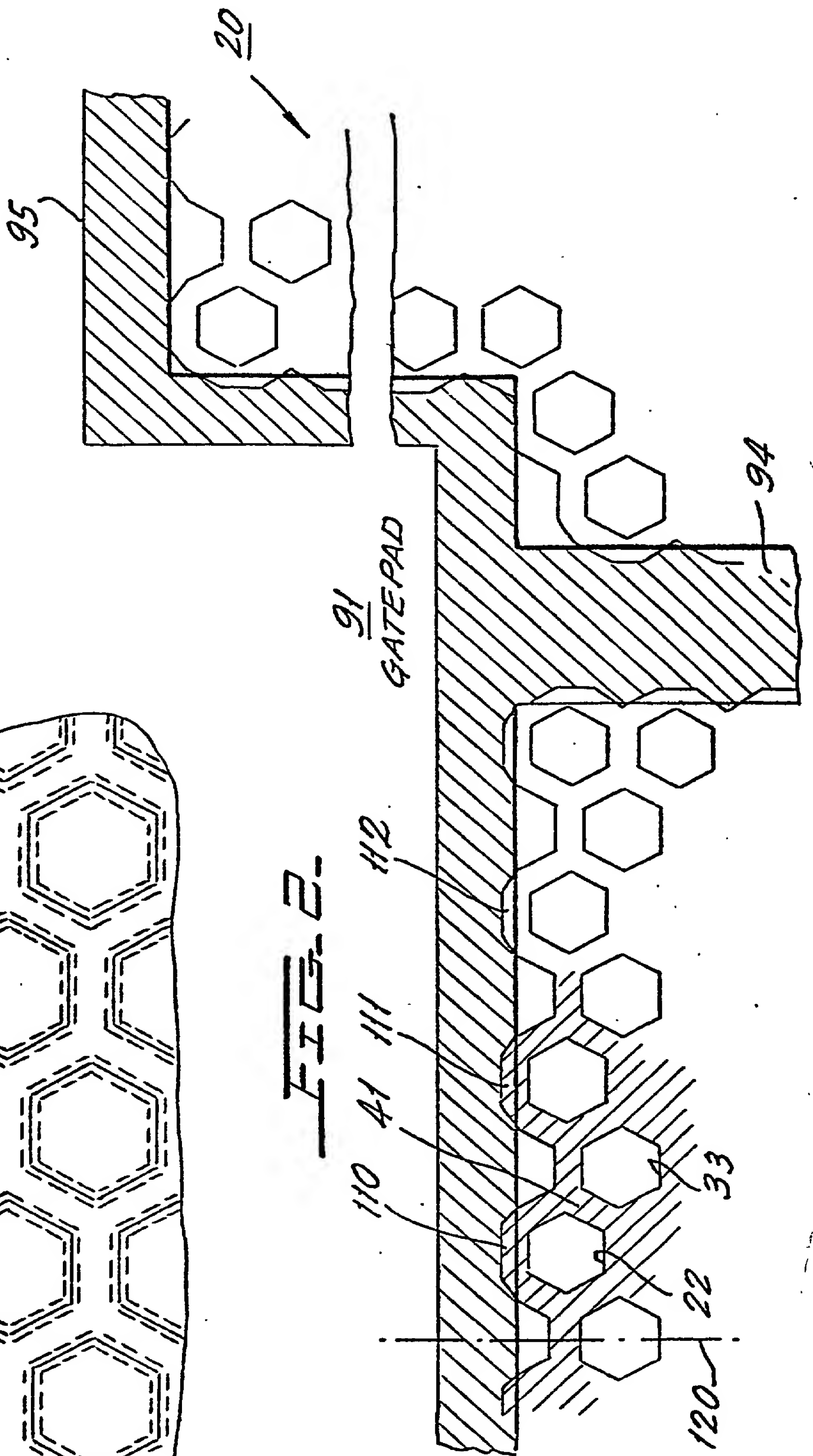


FIG. 4

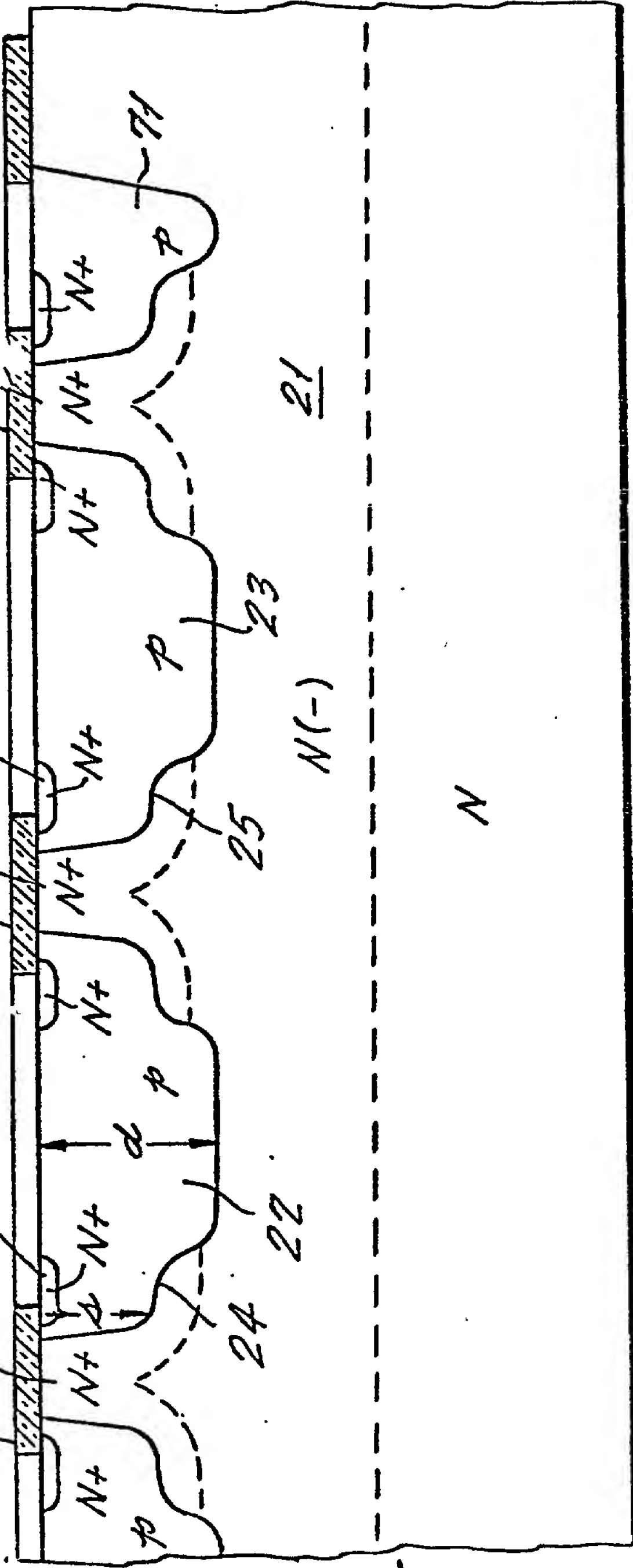
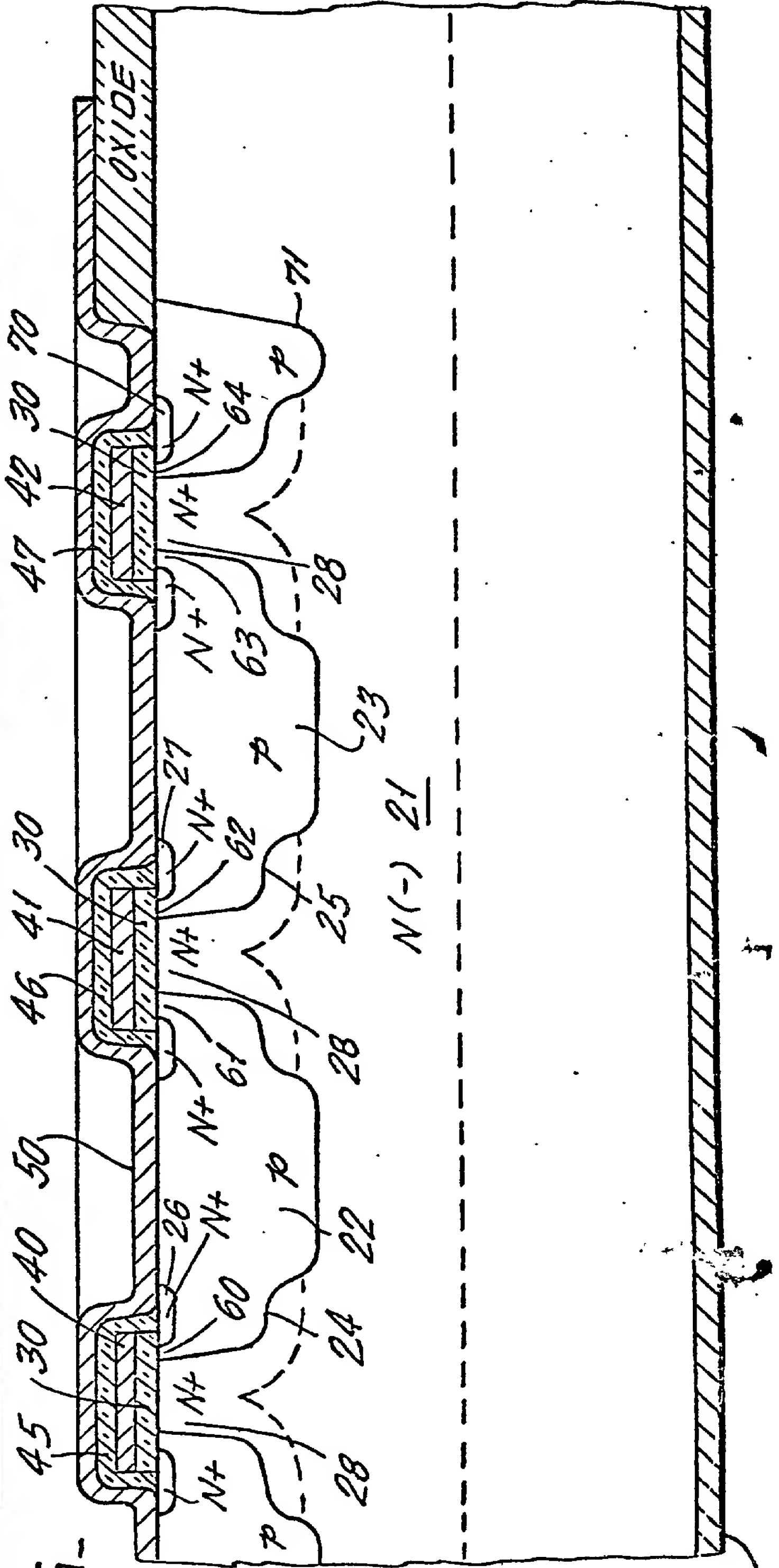


FIG. 5



over